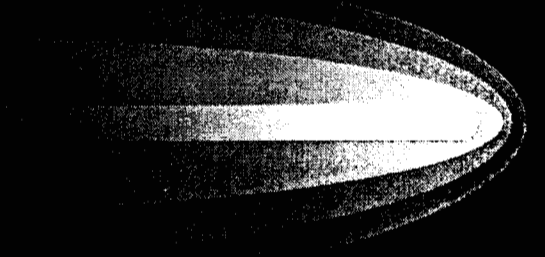
Rapid Development and Infusion



Program Architectures and Processes Supporting Faster, Better, Cheaper Technology

Stephen Prusha
Jet Propulsion Laboratory

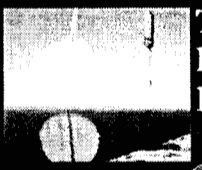
Missions in the Next Millenium

- Characterized by a move from discovery to exploration and from observation to prediction
  - More invasive
  - More extreme and diverse environments
  - Longer duration
  - More complex
- Add less available funding and a requirement for greater frequency,

FBC is here to stay

- Mission community is moving to respond accordingly
- What has technology community done to respond?

Example - Planetary Roadmap

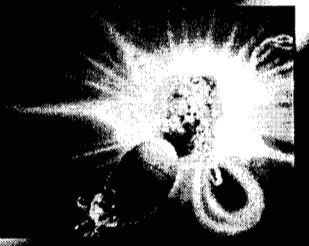


Titan
Prebiotic
Lab

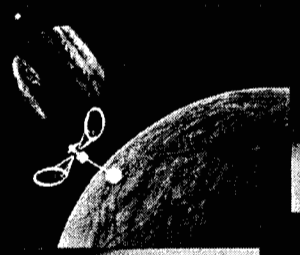
Neptune
Orbiter

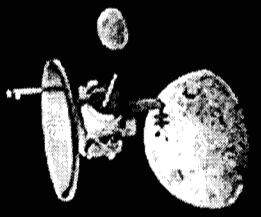
Comet
Sample
Return

Near-Sun
Environment



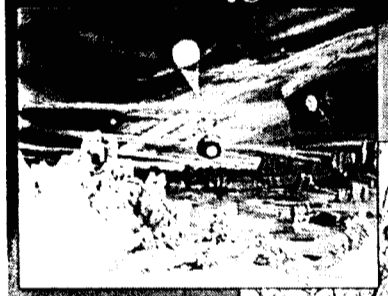
Europa Oceans





Pluto and the
Distant Objects

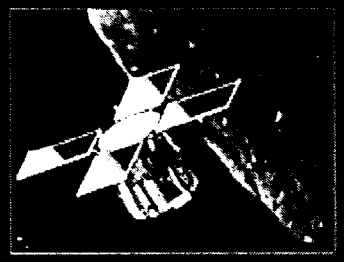
Cassini/Huygens

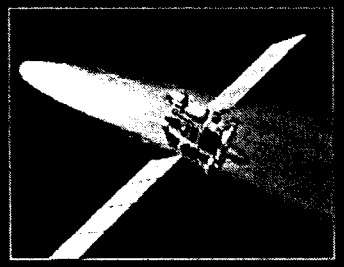


Galileo-Europa

Example - Small Body Roadmap

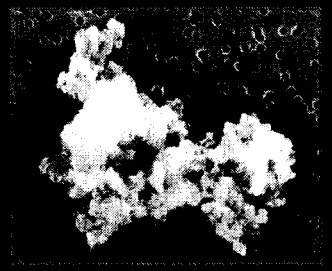
Near-Earth Asteroid Rendezvous

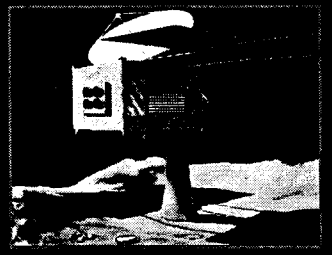




Access and Autonomy: Deep Space 1

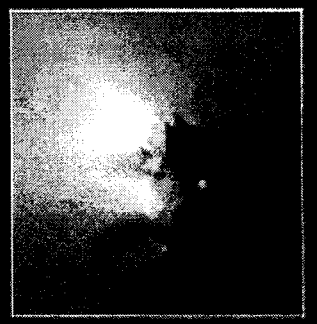
Comet Dust Sampling: "Stardust"

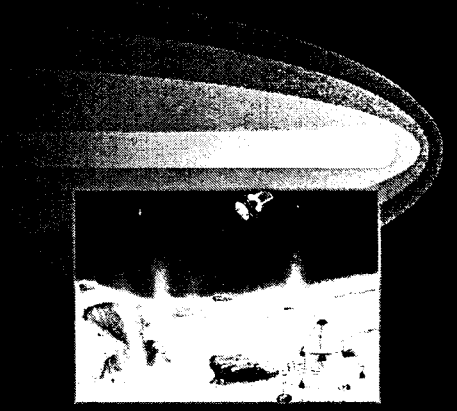




Asteroid Sampling and Mobility: MUSES-C

Comet Nucleus Tour: "CONTOUR"



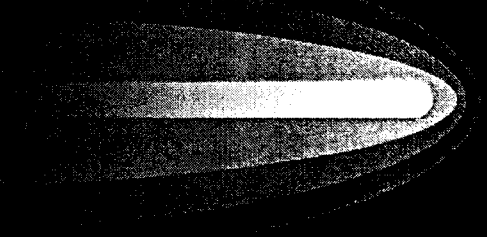


Comet Nucleus Sample Return

FBC Technology

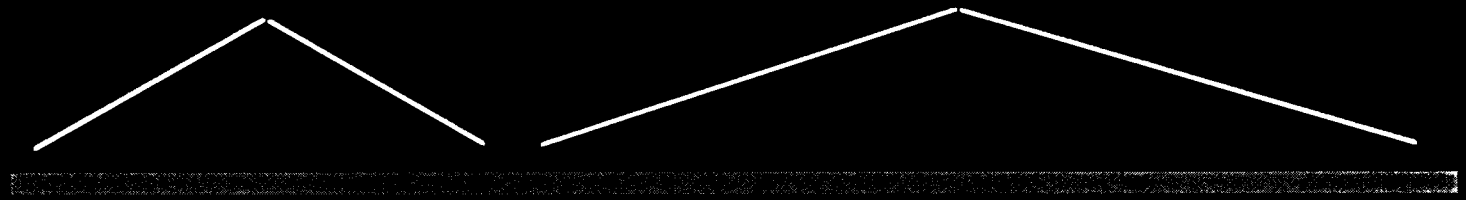
- Achieving FBC technology requires significant
  - Acceleration of technology development
  - Improvements in both the timeliness and likelihood of infusion

Accelerating Technology Development



Focus on richness and diversity of technology portfolio and on accelerating to Proof-of-Concept

Focus on rapid infusion to catalyze maturation - i.e. get in the "pull" mode ASAP



1 2 3 4 5 6 7

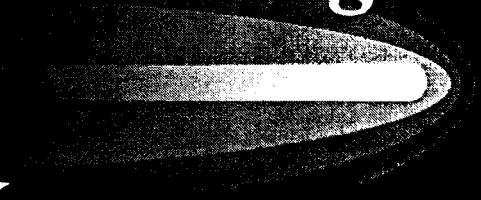
Fundamental Technology Research

Proof of Concept

Flight Validation

Technology Readiness Level

The Risk Challenge

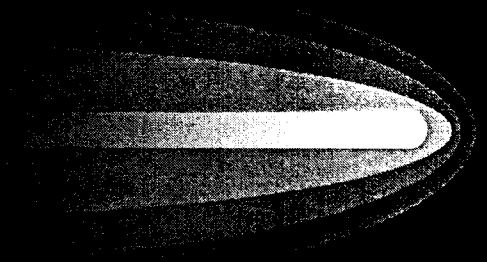


- FBC must address the fourth element - ***risk***
- Risk, in the form of new technology, represents a *negative* influence on schedule and cost
  - Drives missions to COTS solutions - not acceptable for FBC in a more aggressive mission environment
- Retiring risk more effectively is likely the most critical factor for both accelerating development and gaining acceptance by mission community (infusion)
  - So where in the cycle do we address?

Common Failures Seen in Technology Development/Infusion Survey

- Most common failures in a recent survey of 23 "typical" product development tasks
  - Poor packaging concepts
  - Used unqualified materials
  - Flight manufacturing techniques not used
  - Poor mechanical design
  - Lack of good documentation of interfaces
  - CAE tools not fully utilized (FPGA, ASIC, simulation, PWB fab)
  - Thermal stability issues/sensor calibration
  - ESD accidents
  - EMI/EMC
- Total success rate overall was surprisingly poor - under 30%
- Technologies failed to deliver as promised generally due to failures considered mundane by technologists
- The technology development community and flight project communities did not interact efficiently nor early - cultural differences were not addressed
- Project mentality to mitigate risk prevailed, and products with questionable TRL were quickly discarded and replaced with COT solutions

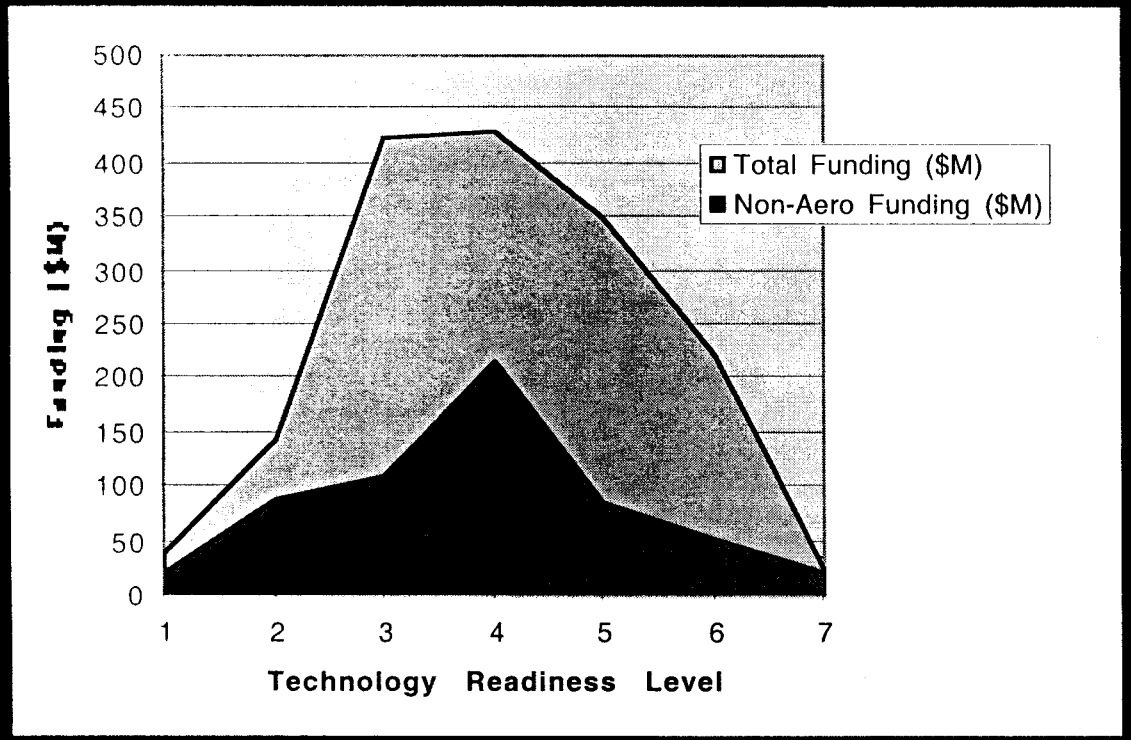
Accelerating To Proof-of-Concept



- Early in cycle, technology development focus is, and should be, on proving innovative and mission enabling technology concept, not on demonstrating product maturity necessary for missions
- But Proof-Of-Concept is poorly established and is interpreted differently by two communities
  - Projects/Missions expect "proof-of-concept" to be proven for their mission, for use in their environment
  - Technologists are seeking 1st order functional demonstration
- Principal benefit to evaluate at P-O-C is to synchronize, negotiate agreement between communities for each technology
  - Identify major technology development hurdles which may prevent a product from reaching missions
  - Identify major (project specific) engineering hurdles which may prevent infusion, and must be dealt with in the future, but are beyond the immediate concern of the technologist

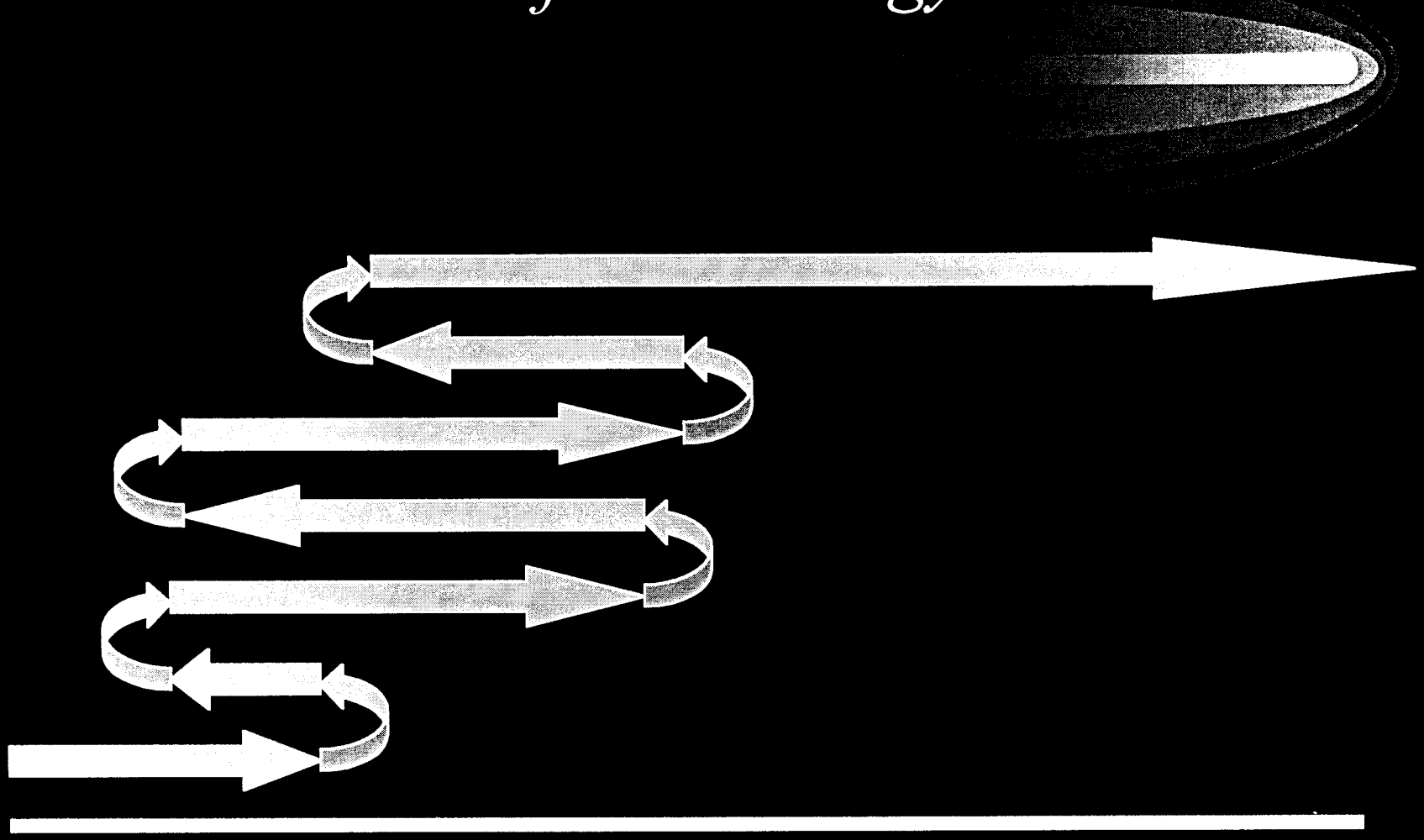
Key is to identify the right ***target*** - to create a sense of urgency on the part of the developer and an objective mechanism to assess real maturity

The "Bathtub" Myth



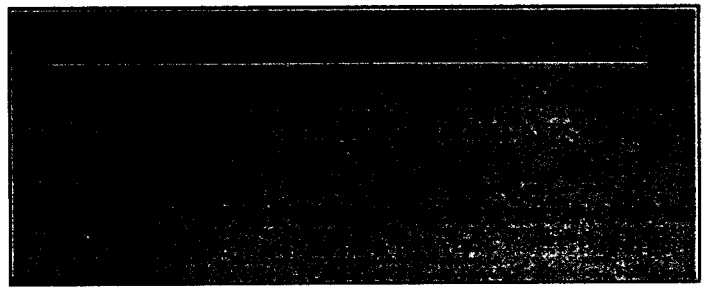
- It is often stated that a lack of funding in mid-TRL (4-7) programs is a critical impedance to technology development
  - What is the nature of the "bathtub"?

The Nature of Technology Maturation



Technology Readiness Level

CETDP Technology Infusion and Investment Analysis at JPL



REAL OPTION
INVESTMENT TOOL

TECHNOLOGY
PAYOFF
DISTRIBUTIONS

MISSION
SETS

REAL OPTION
VALUATION MODEL

TECHNOLOGY PRODUCTS
AND PLANS
CETDP DATABASE/
NASA INVENTORY

TEAM X/T
and Mission Studies

"Roadmapped"
MISSION
SETS

MISSION
TECHNOLOGY
REQUIREMENTS
(SEE ABOVE)

PRECISION
TREE

TECHNOLOGY INFUSION
AND MATURITY ASSESSMENT
TOOL

TIMA/DDP

OPTION VALUE
OF PRODUCTS

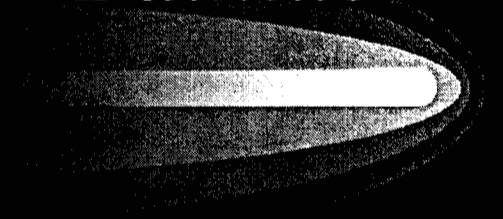
COMPARE PLANS
VS.
REQUIREMENTS

TECHNOLOGY
GAPS

TECHNOLOGY
ALIGNMENT
OPTIONS

February 2000 KAH

Rapid Development in the "Bathtub"



Some investigation reveals that

- Most technologies transition from TRL 4/5 directly to flight (few require in-space subsystem or system-level validation)
- Nature of technology maturation suggests that many develop at TRL 3/4 for long time before they are ready to move on
- Risk abatement on part of focused programs tends to drive them toward higher-TRL investments

As a result, the "bathtub" is *likely a natural profile* - and additional funding applied would, over time, result in nothing more than a larger bathtub

  - Supported by evidence that "focused" programs represent largest space technology investment in NASA
  - Little evidence exists that relevant products, truly at a high maturity, are unable to find infusion paths, or that funding is the problem

Accelerating development through mid-TRLs is more likely an issue of "jumping" the bathtub rather than "filling" it

Impedances to Rapid Development

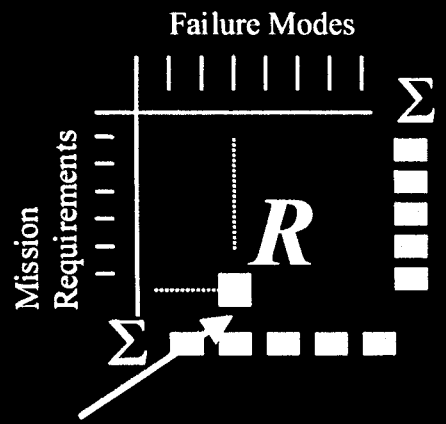
At Low TRLs

- Lack of reliability and duration of support
- Lack of urgency
- Lack of feedback from customers or peers
- Insularity
- Effective risk management

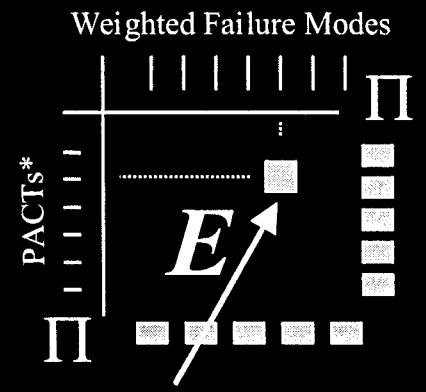
At High TRLs

- Risk aversion
- Lack of access into customer base
- Reliance on single infusion path
- Requirement for flight validation

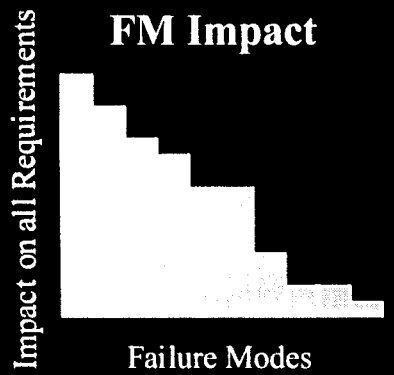
Accelerating Risk Retirement



Impact of a given FM on a particular requirement (e.g. % of requirement lost if FM occurs)



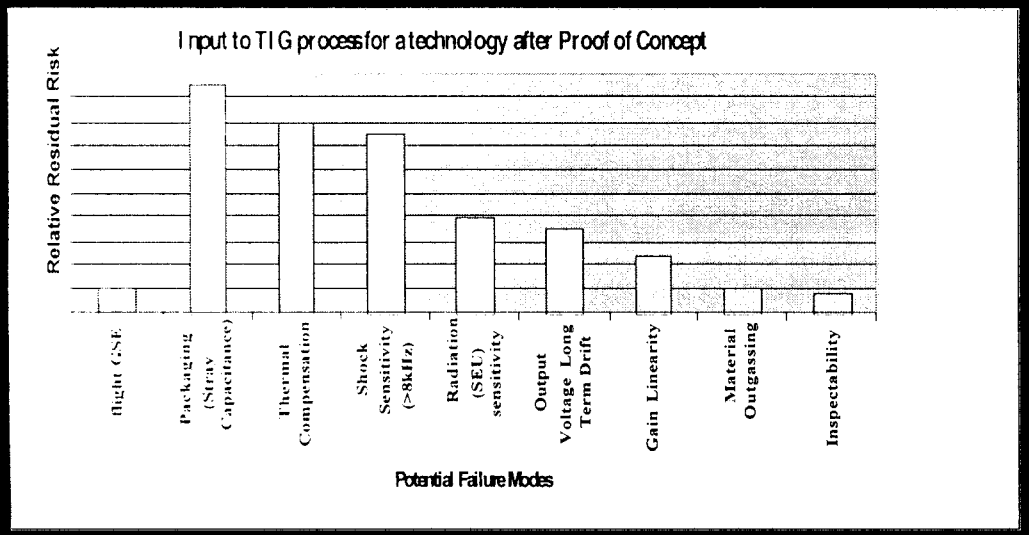
Effectiveness of a given PACT* on a particular FM (e.g. % chance of failing to detect or prevent)



How much it affects me x How much I missed it = Residual risk

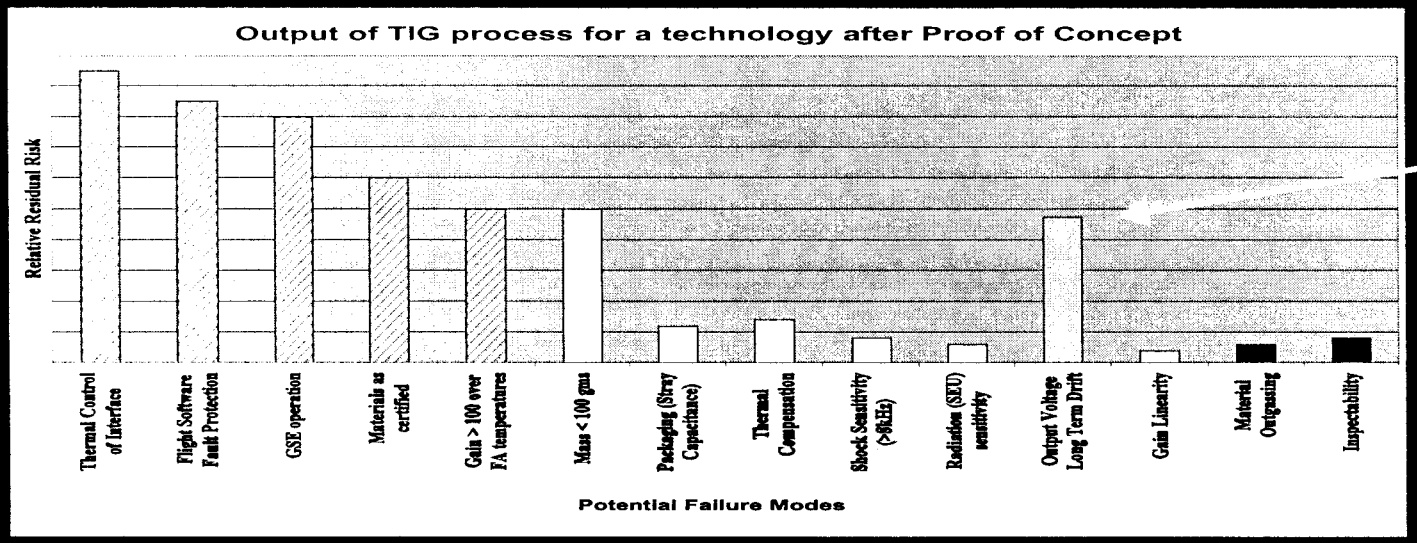
* PACTs = Preventative measures, Analyses, process Controls and Tests = All detection/prevention options

Accelerating Risk Retirement



•Process identifies project/engineering issues not previously considered in the technology development phase

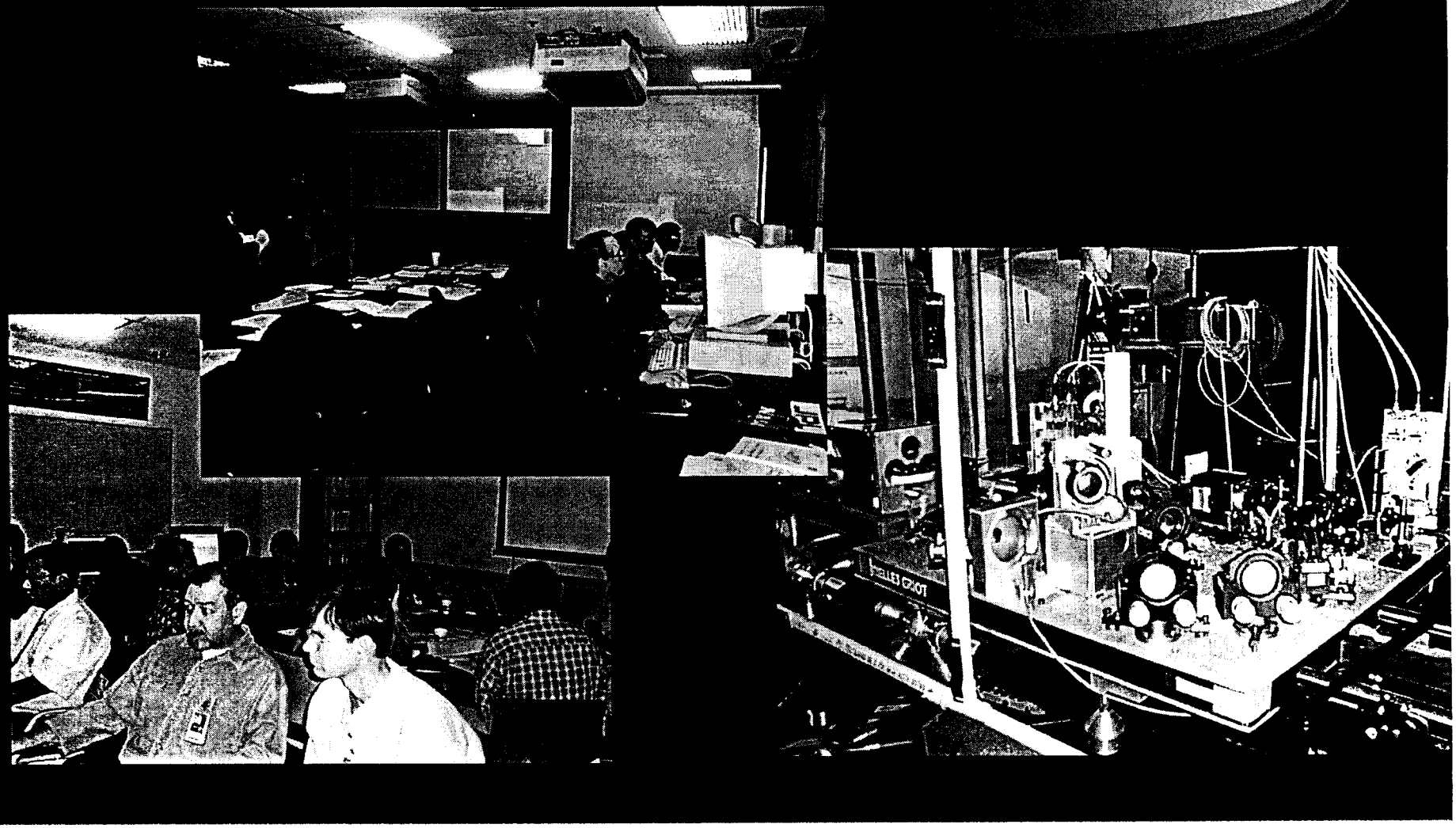
After application of TIG process and consensus PACT options



•Development issue underestimated before TIG process
• Development effort applied in most *effective* areas - don't worry about others
• Project focus/funds should be on blue hatched lines to begin to lower project risk

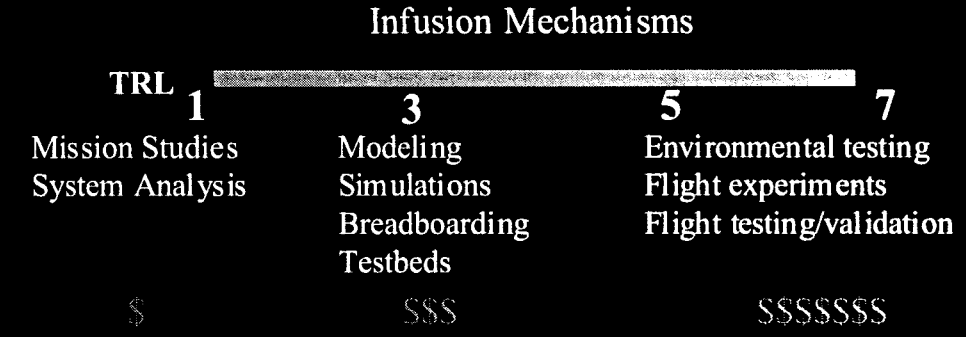
Engineering/Project Issues ◄——► **Technology Issues**

Accelerating Infusion

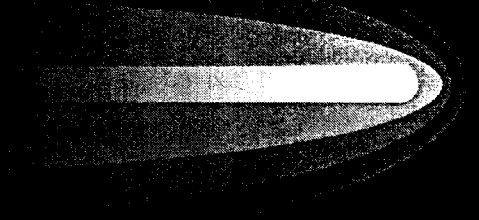


Some Observations on Infusion

- Key to successful infusion is *early penetration* into customer base, often while technologies and missions are still immature
- History indicates that show stoppers which prevented technology infusion after TRL 3 were often "engineering" issues and needed the attention of a broader multi-disciplined community **earlier**
- Infusion is continuous - and occurs at *all* TRLs
  - Mechanisms vary at each level, and between different organizations



Traditional Infusion Models

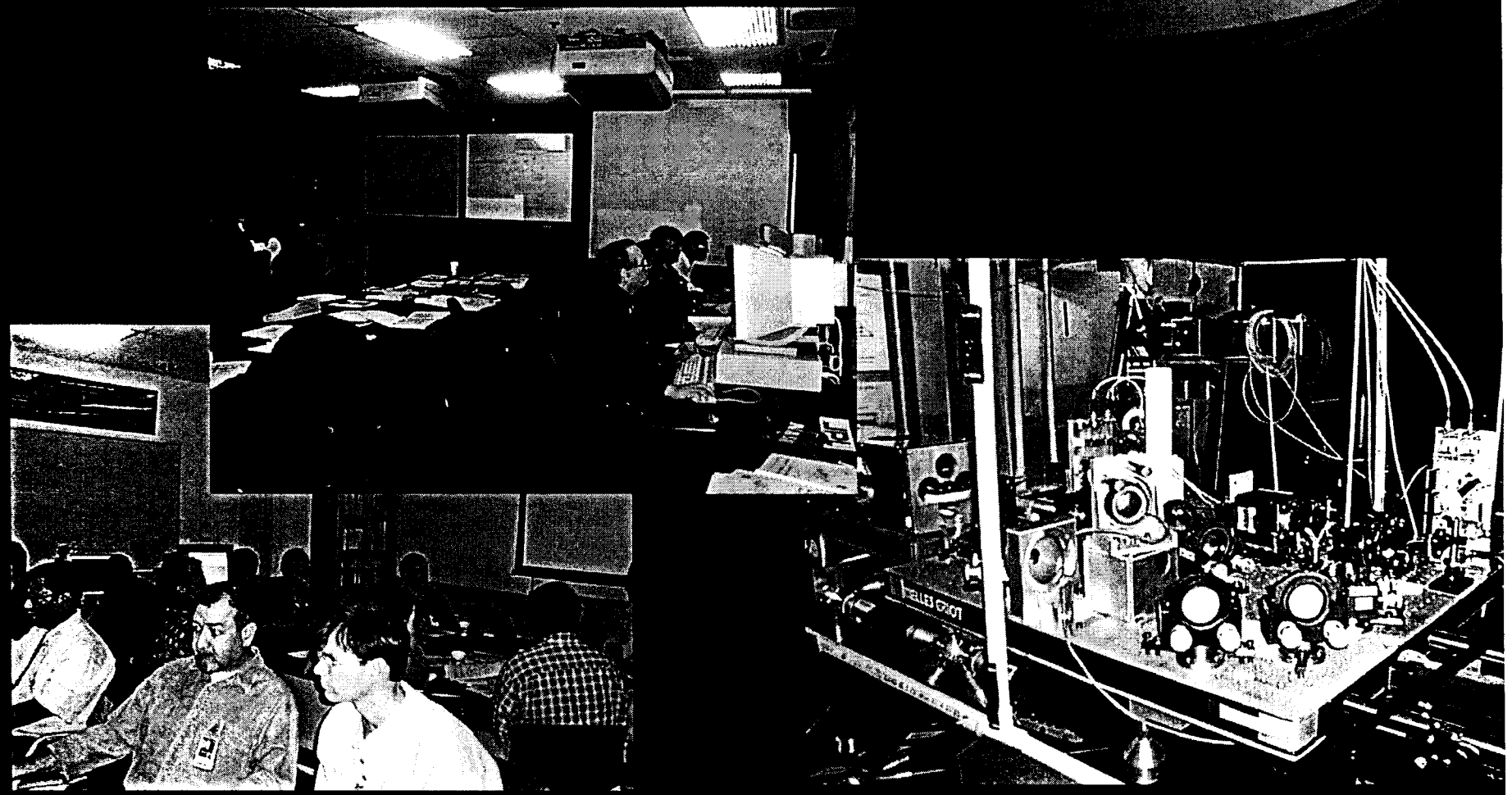


- Direct - e.g. ARPS
  - Brute force method, effective but not very nimble
- Commercial - e.g. ELVs, aeronautics
  - Relies on commercial market viability
- Evolutionary/Opportunistic - e.g. MLS
  - Difficult for enabling technologies?

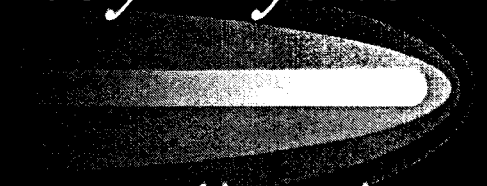
Impedances to Rapid Infusion

- Project's risk aversion
- Lack of *relevant* validation
- Differing assessments of technology maturity
- Rapid and timely access to projects
- Institutional biases
- Competitive nature of Centers
- Cultural incompatibilities (tech vs. mission)
- Reliance on single infusion mechanisms
- NIH
- Lack of mechanisms to provide infusion pathways
  - Especially within Agency
- Introduction too late in cycle

Accelerating Infusion



The FBC Technology Dependency Myth?



- Technology has been accepted as an obvious factor in reducing cost and improving performance, but
  - **New or immature** technology has quite the opposite effect
  - Most technologies do not reduce risk until they are well established
- In practice, reliability is more important than performance in reducing schedule and cost
- Result has been, and may continue to be: retire risk by dumping *new* technology
  - Treats technology as a *cost*, not an *investment*
- Technology funding has reflected this trend, as it has been reduced significantly since 1992
  - Extreme pressure on cost, coupled with many, more aggressive mission commitments in all Enterprises, leaves NASA with few alternatives
- One conclusion is that this "double whammy" - less technology funding coupled with a more risk averse mission community - now leaves the technology community with far less ability to affect the FBC paradigm

Changing the FBC Technology Impact

- Must solve the *risk* challenge
- Market will provide the Better and necessitate the Cheaper
- Schedule (Faster) will be determined by risk retirement
  - Anyone remember "technology driving missions"?
- Are the plates too full everywhere to have adequate *investment* for technology?
- Do we have the patience and discipline to wait for the *return* to materialize?